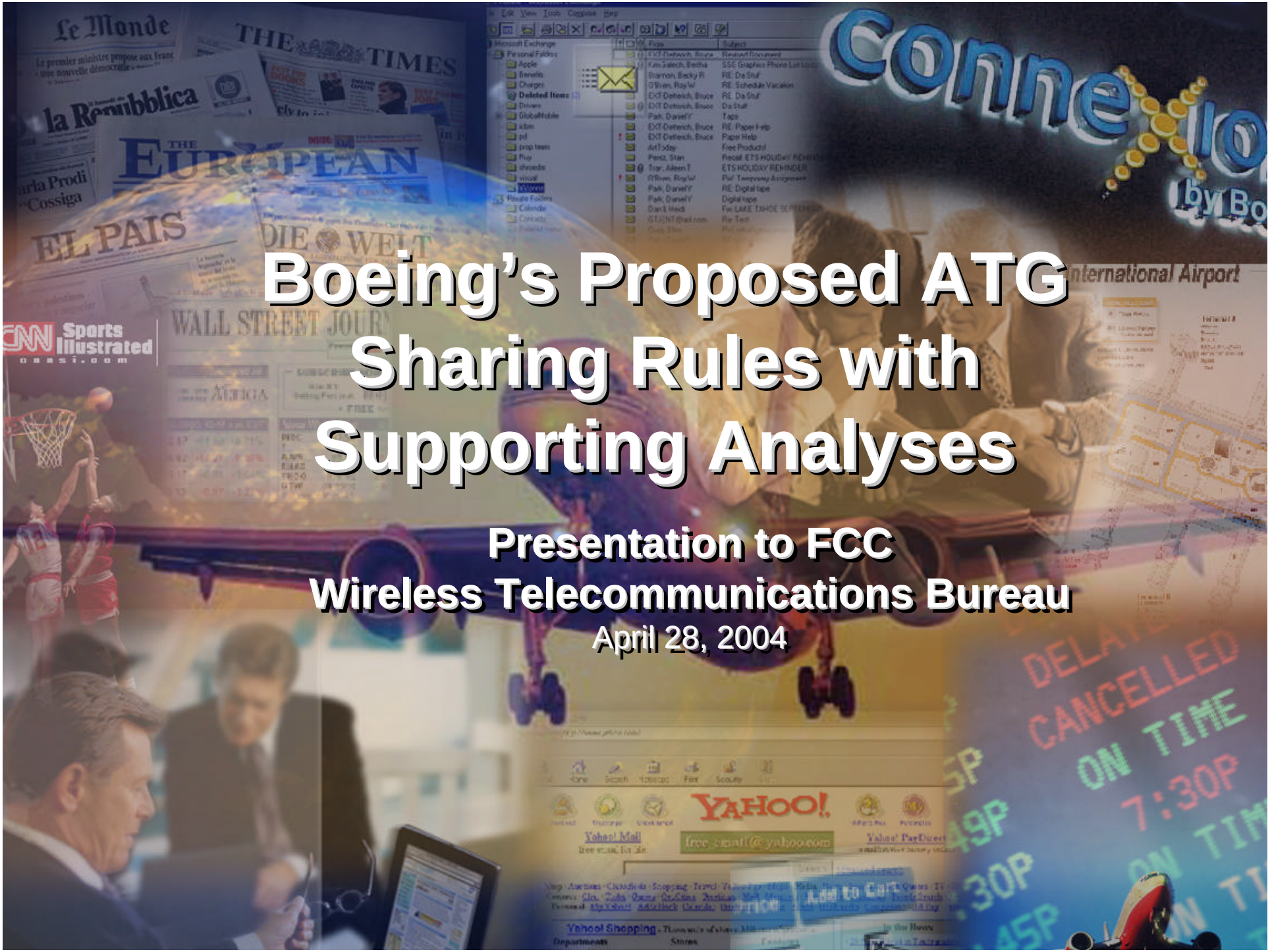


Boeing's Proposed ATG Sharing Rules with Supporting Analyses

Presentation to FCC
Wireless Telecommunications Bureau
April 28, 2004

Overview

Technically feasible

- Simple rules
- “Plain old base station” technology
- Simple aeronautical antenna – less expensive than many deployed today

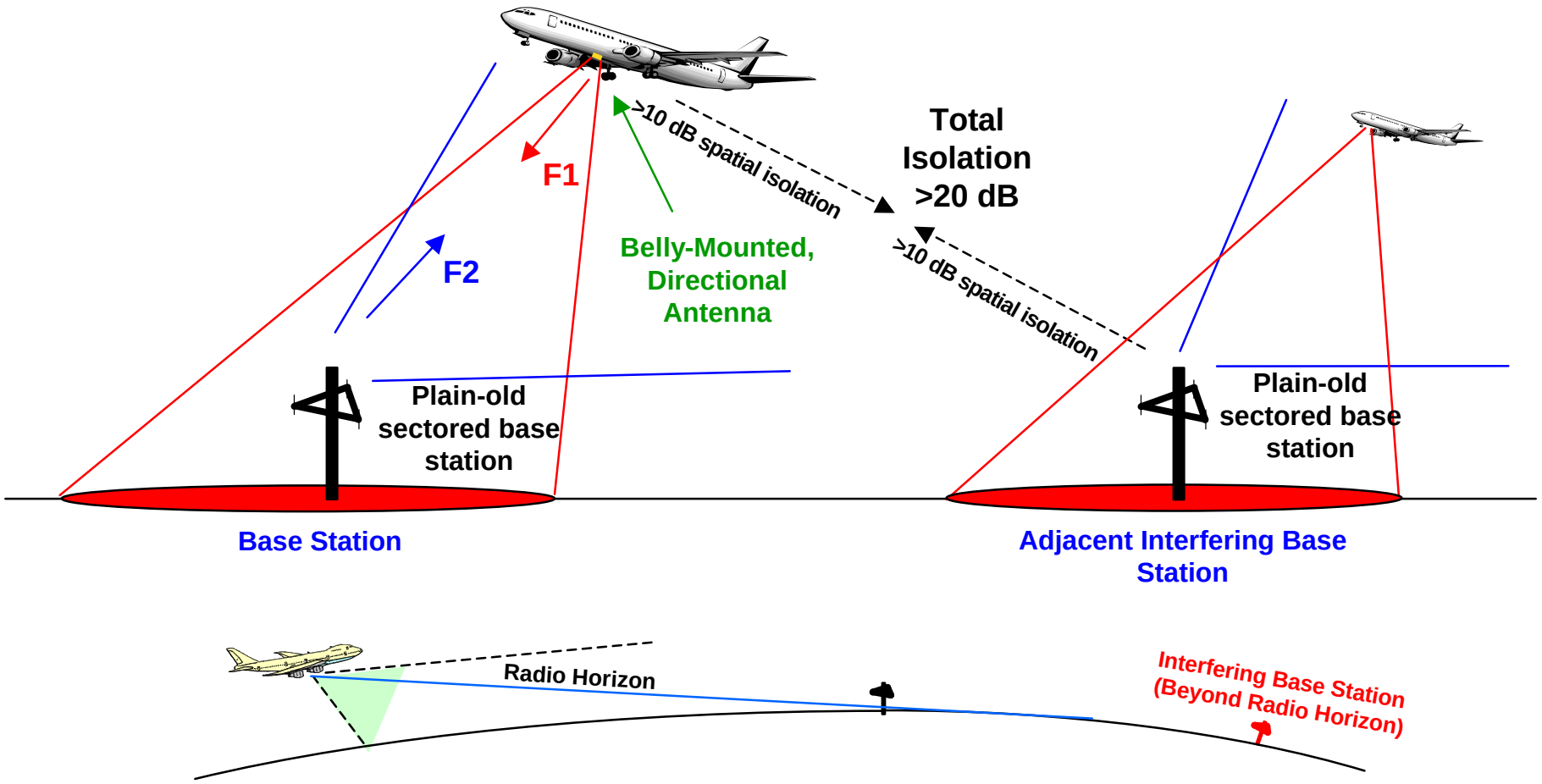
Pro-competitive

- Three service providers can share spectrum
- Concerns of other participants addressed
- Accommodates transition of the incumbent system

Efficient

- Gives service providers maximum latitude to choose technologies and system design
- Encourages efficient use of ATG spectrum
- Allows service providers to upgrade technology
- Open items can be addressed via comments within current NPRM

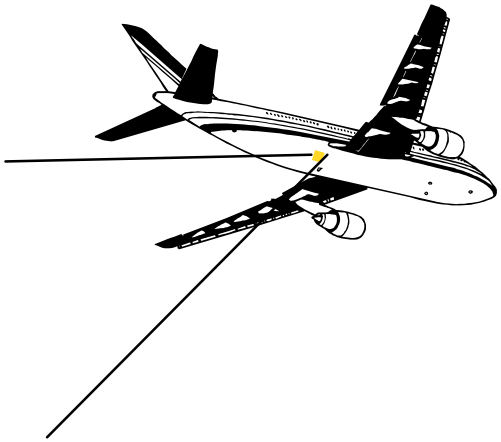
ATG Technical Thesis & Solution



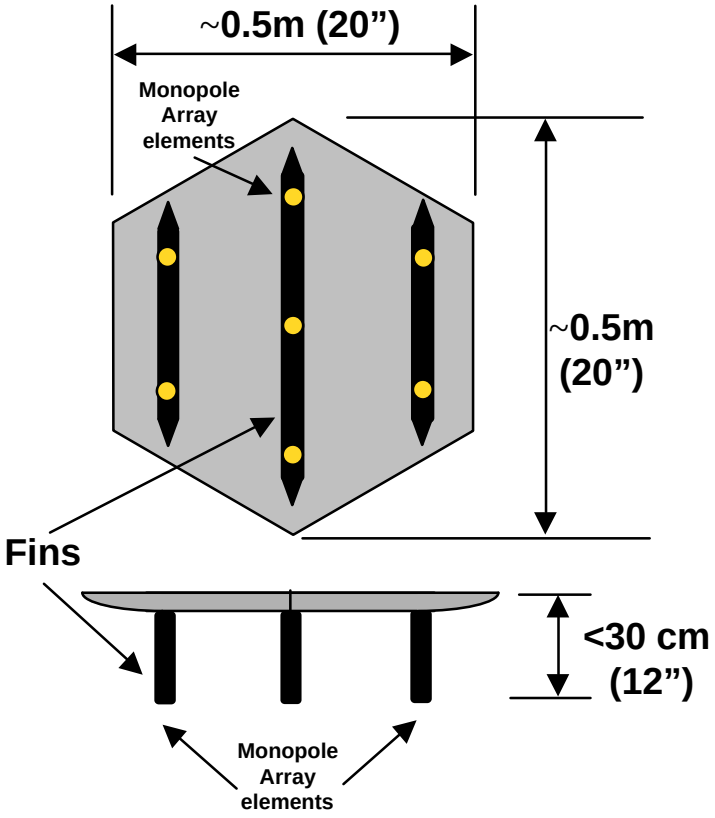
Thesis

Spatial isolation provided by sectored base station antennas, directional aeronautical antennas, and the curvature of the earth, allow multiple service providers to serve the entire addressable market while sharing the existing ATG spectrum.

Directional Aircraft Antenna



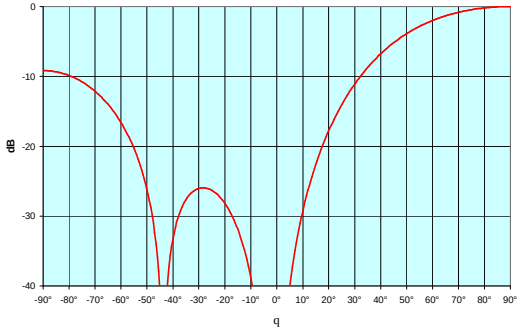
7-Element Array



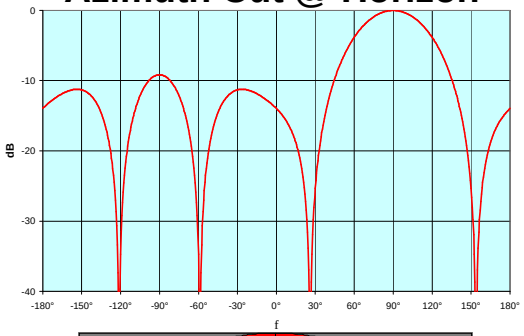
Weight ~ 10 kg (22 lbs)

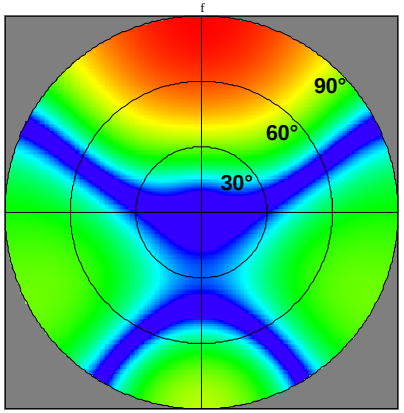
Simple and inexpensive aero antenna provide >10 dB spatial isolation.

Elevation Cut



Azimuth Cut @ Horizon





Pointed to Horizon

Note: Substantially improved performance can be achieved by bore sighing away from interfering base station or adaptive nulling.

“Plain-Old” Base Station Antenna
6-Sectors (60°)

DECIBEL®

DB876G60A-XY

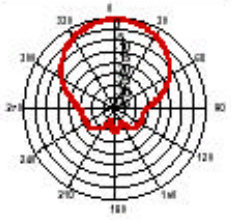
15 dBd, Panel Antenna
806-896, 870-960 MHz

806-896 MHz
870-960 MHz

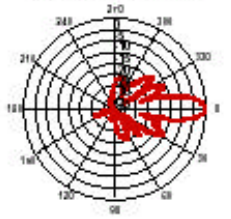
GEN3VPOL™

- Air dielectric feed system featuring no screws, welds, solder or rivets in dipole feedpoint
- Low loss feed system provides improved gain per unit length
- Low noise due to superior intermodulation performance
- Low profile appearance and low wind loading profile for easier zoning approvals

60°



Horizontal 850 MHz (Tilt=0)



Vertical 850 MHz (Tilt=0)

ELECTRICAL		
Frequency (MHz):	806-896	870-960
Polarization:	Vertical	Vertical
Gain (dBd/dBi):	15/17.1	15.5/17.6
Azimuth BW:	60°	60°
Elevation BW:	12°	11°
Beam Tilt:	0°	0°
Front-to-Back Ratio* (dB):	25	25
VSWR:	<1.33:1	<1.33:1
IM Suppression - Two 20 Watt Carriers:	-150 dBc	-150 dBc
Impedance:	50 Ohms	50 Ohms
Max Input Power:	500 Watts	500 Watts
Lightning Protection:	DC Ground	DC Ground

MECHANICAL	
Weight:	10 lbs (8.6 kg)
Dimensions (LxWxD):	72.2 X 12.5 X 5 in (1820 X 318 X 127 mm)
Max. Wind Area:	6.3 ft² (0.59 m²)
Max. Wind Load (@ 100mph):	250 lbf (1112 N)
Max. Wind Speed:	125 mph (201 km/h)
Radiator Material:	Aluminum
Reflector Material:	Passivated Aluminum
Radome Material:	ABS, UV Resistant
Mounting Hardware Material:	Galvanized Steel
Connector Type:	7/16 DIN - Female (Back)
Color:	Light Gray
Standard Mounting Hardware:	DB380 Pipe Mount Kit, included
Downtilt Mounting Hardware:	DB083, optional
Opt. Mounting Hardware:	DB084-AZ Azimuth Wall Mount

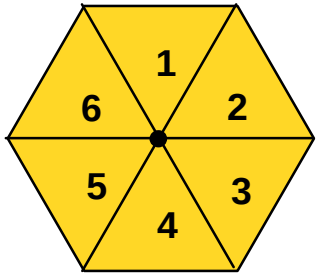
ANDREW

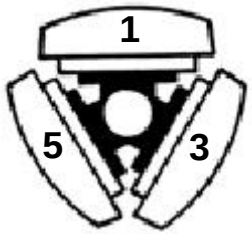
Andrew Corporation
9605 Stemmons Freeway
Dallas, Texas U.S.A. 75247-3701
Tel: 214.631.0310

Fax: 214.631.4706
Toll Free Tel: 1.800.648.6342
Fax: 1.800.229.4706
www.andrew.com

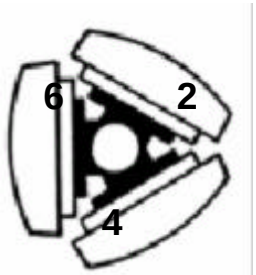
Date: 7/24/2003

dbtech@andrew.com



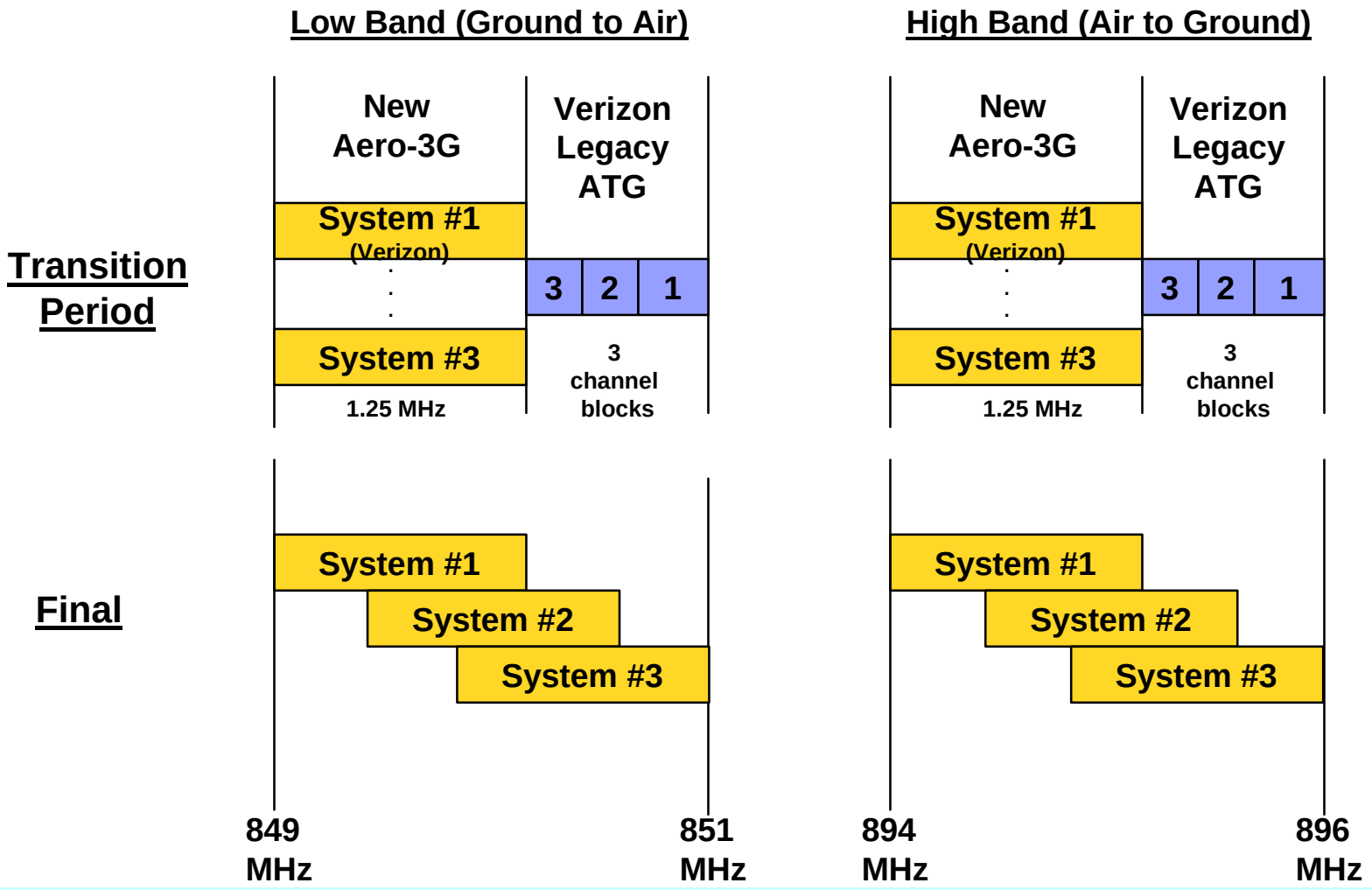


6-Sector Mast-Mounting Configuration



This product has been in production for twenty years. Same product line includes 45° (8-sector) and 35° (10-sector antennas

ATG Spectrum Channelization



Our channelization plan:

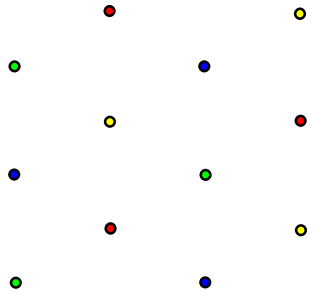
- accommodates 3 systems (more with state-of-the-art technology)
- provides a transition plan
- Uses overlapped 1.25 MHz channels to accommodate all CDMA2000 standards.

Proposed ATG Rules

Two Approaches That Work

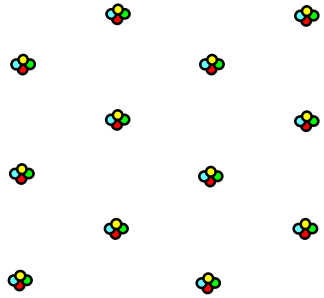
•We studied different approaches for co-freq sharing between multiple CDMA systems.
•We found two opposite approaches that technically work.

Separated & Uncoordinated Base Stations



- Requires no coordination between systems
- Service providers are free to choose technology and standards
- Service providers can independently upgrade their networks
- Requires minimum separation distances between base stations
- Requires emission level limits for BTS and aircraft

Common & Coordinated Base Stations



- Similar to current ATG rules
- Requires service providers to share base stations*
- Locks service providers into current standards and technologies
- Prevents system upgrades and innovation
- Discourages efficient use of spectrum

*Current rules require co-location of base stations within several miles. CDMA with shared Walsh codes requires less than 30m separation between antennas, which is effectively the same tower. Shared BTS are becoming increasingly common.

•We recommend separated & uncoordinated base stations
•Proposed rules & analyses are based on this approach

Rule Strategy

- Make rules as simple as possible.
- Do not require any coordination or synchronization between service providers and base stations.
- Allow service providers to implement their systems with whatever design and technology they choose.
  - Do not mandate any antenna implementation
  - Do not mandate any particular CDMA standard
- Rules are designed to encourage efficiency & limit interference

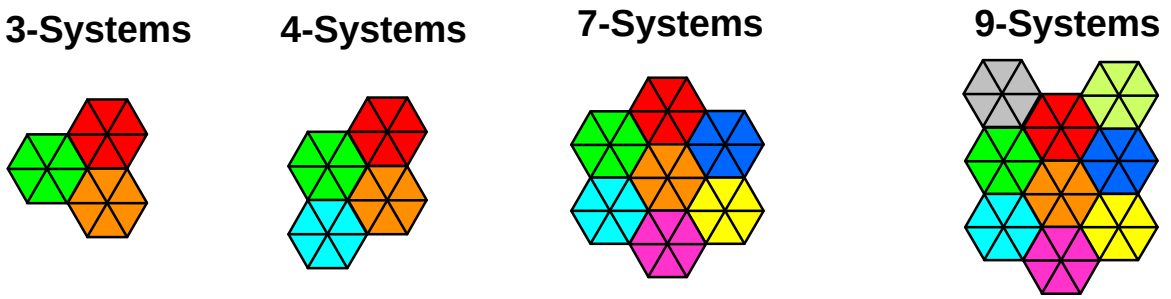
Proposed Base Station Separation Distance Rules

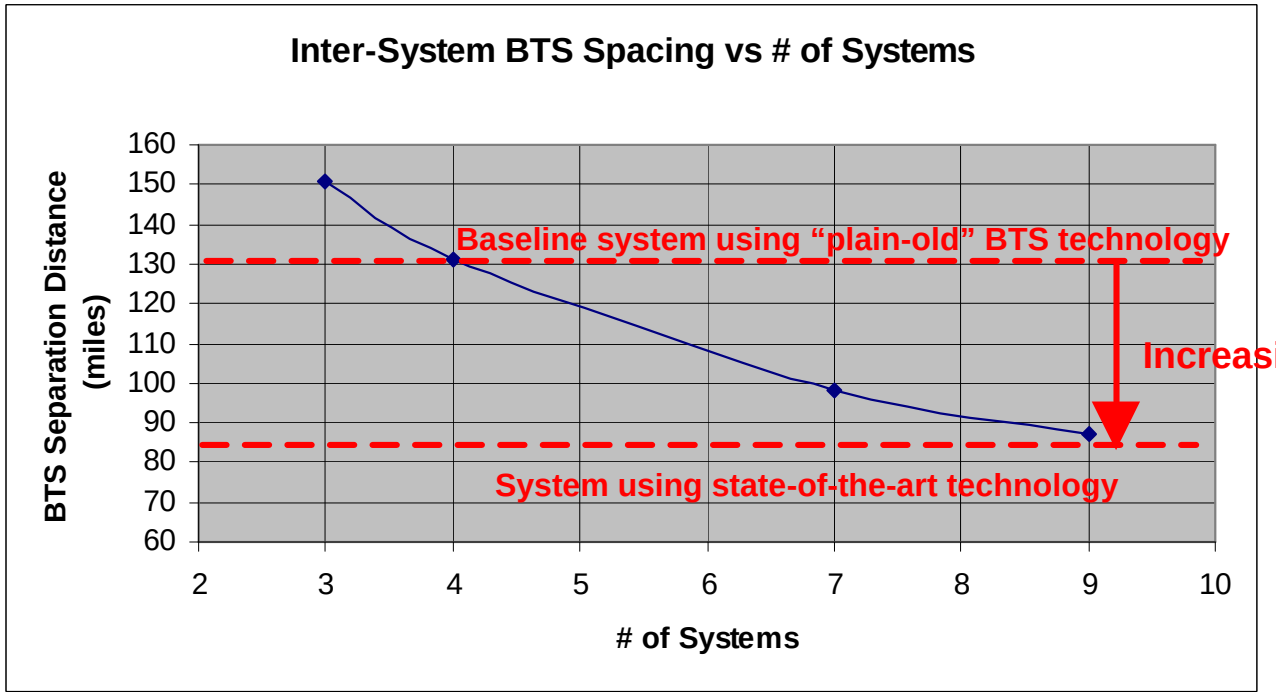
- Inter-System BTS Separation Distance
  - Base stations (BTS) from different systems shall be separated by at least 131 miles (211 km).
- Intra-System BTS Separation Distance
  - Base stations (BTS) from the same system shall be separated by at least 227 miles (366 km).

These separation distances allow:

- **Continuous coverage above 10,000' AGL**
- **Accommodates 3 systems on irregular grid.**

BTS Separation Distances – Regular Grid





- Inter-System BTS spacing reduces as number of systems increases.
- More sophisticated technology is required to isolate the serving BTS as the # of systems increases
- Analysis shows that 4 systems can be accommodated at a BTS spacing 131 miles

BTS Spacing - Justification

- The intra-system spacing must be within the radio horizon-to-horizon (RH-H) distance from the aircraft.
  - Radio horizon (RH) distance for an aircraft at 10,000’ to a 50’ base station on level ground is 151 miles (244 km) or 302 miles (488 km) RH-H.
  - The proposed intra-system separation distance (227 miles) is well within the RH-H of 302 miles which allows for uneven terrain effects.
- The previous analysis shows that 131 miles inter-system BTS spacing is consistent with 4 service providers in regular grid. Analysis shows that this configuration works.
- To increase flexibility in base station placement, 3 systems are used with the same inter-system BTS separation, allowing the intra-system separation to be reduced 227 miles.
- This allows considerable latitude for off-grid placement of base stations.
  - Separation between 227 miles and the RH-H are possible.

EIRP Limit Rules

- The EIRP spectral density emitted from any base station shall not exceed X dBW/Hz in any direction within the ATG band.
- The aggregate EIRP spectral density from all aircraft operating on one system within the radio horizon of another system's base station shall not exceed X dBW/Hz in the direction of that base station and within the ATG band.

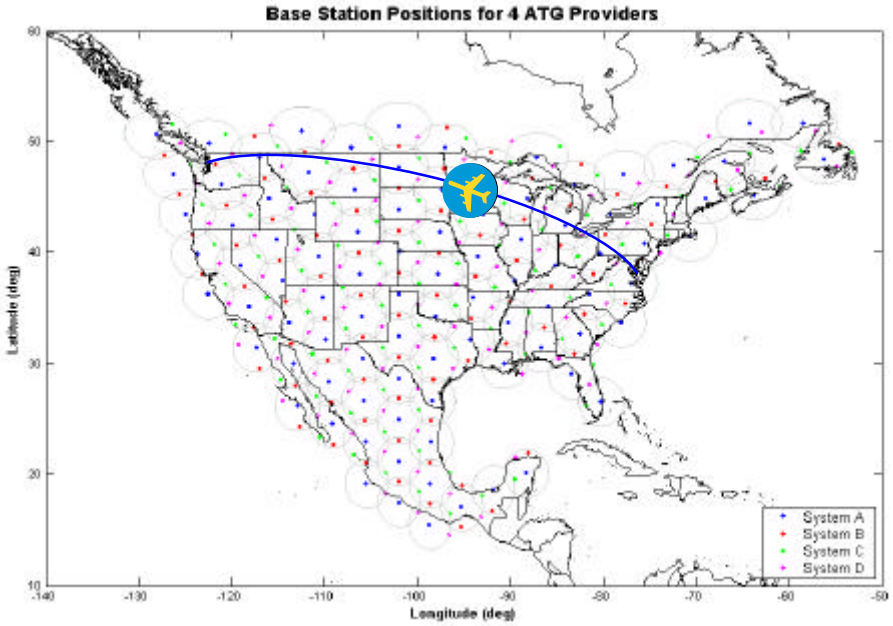
These rules allow service providers the freedom to choose any CDMA standard or technology (BTS and aero antenna designs).

Simulation Results

Simulation Objectives

- Simulation #1 – Prove the Geometry
  - Show that the geometries of multiple system operation avoid scenarios that can produce unacceptable inter-system interference.
    - The “near-far” problem never occurs for the 3 or 4-provider solution.
    - Provide the FCC with a visual demonstration that proves that the geometries work.
- Simulation #2 - Measure system capacity for multiple system scenarios.
  - Vary traffic intensity up to full market load.
  - Determine how many service providers can share ATG spectrum.
  - Evaluate sensitivity to design parameters and technologies.

4-System Geometry – Video Simulation



- Aircraft "flown" from Washington, DC to Seattle, WA
- Connects to blue service provider's base stations
- Interfering base stations are colored red, yellow and green.

Video #1 – Hemi antenna @ 30'K
Video #2 – 7-Element Array @ 30'K

Key to video simulation

- Red beam indicates "near-far" problem. Interfering BTS is within antenna beam and closer than serving BTS.
- Yellow indicates that interfering BTS is within the aircraft antenna beam and radio horizon but at a distance beyond the serving base station.
- Green indicates that only the serving BTS is within the aircraft antenna beam and radio horizon

Results:

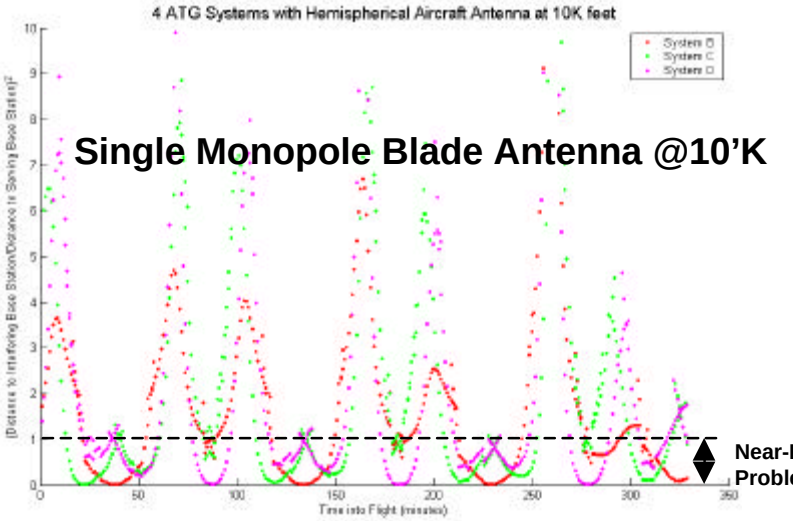
Hemi-Antenna

- Near-Far problem occurs over most of flight

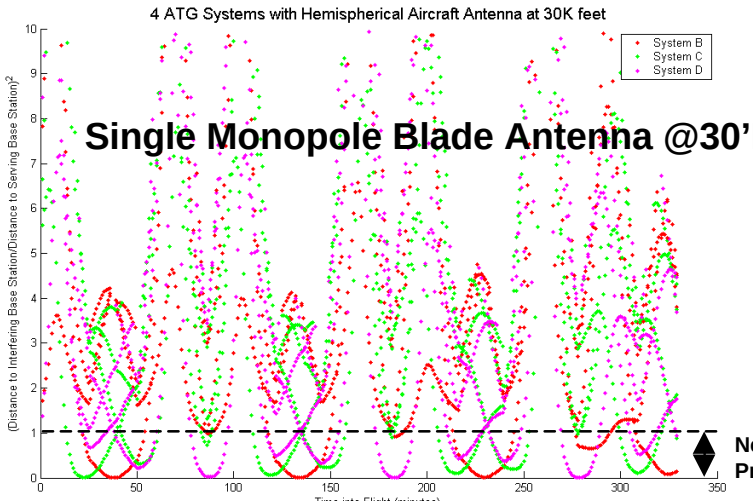
7-Element Array

Near-Far problem never occurs.

4 Systems Geometry – Regular Grid

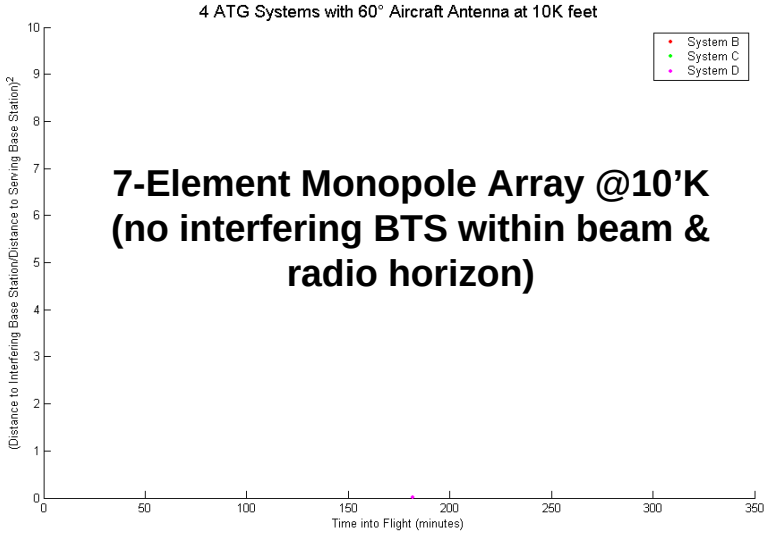


Single Monopole Blade Antenna @10'K

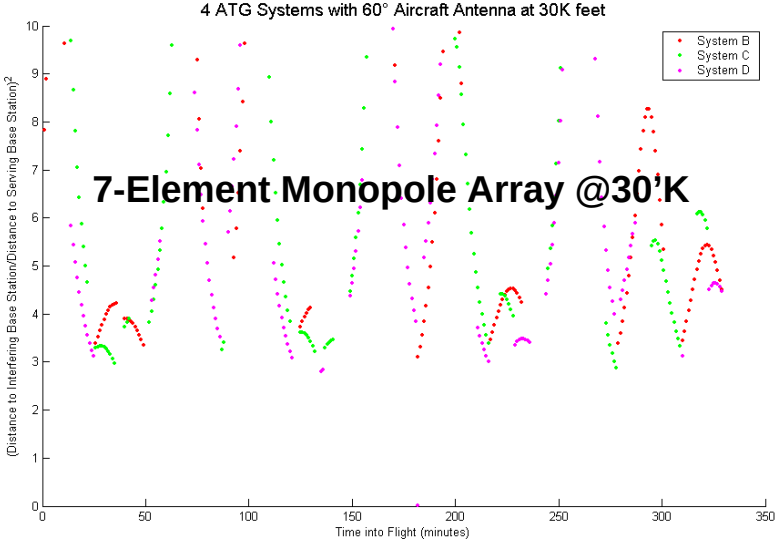


Single Monopole Blade Antenna @30'K

Near-Far Problem



7-Element Monopole Array @10'K (no interfering BTS within beam & radio horizon)



7-Element Monopole Array @30'K

Near-Far problems are completely eliminated by use of directional aero antenna. >4.8 dB Far/Near squared ratio provides sufficient Eb/Io.

Full Simulation

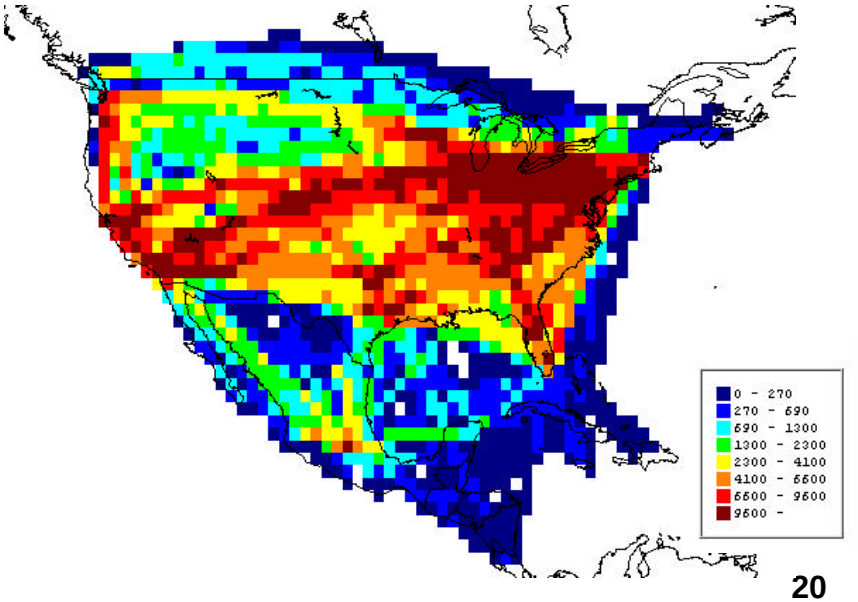
- Measure system capacity
- Determine max number of systems.

Simulation Assumptions

- Nearest BTS coverage
- No coordination between BTS
- Inter-system BTS location spacing for 4 systems (see rules)
- Traffic load = 10, 20, 50, 80,100% of market
  - Market assumptions follow
- No traffic below 10,000’
- 64 orthogonal Walsh codes (out of 128 available)
  - Re-used per sector
- Vertical polarization only
- Directional aero antennas
  - See model
- Single 1.25 MHz CDMA channel up & down.
- Results multiplied by 1.375 to account for second overlapped channel.
- Limited aircraft EIRP (see rules)
- Limited base station EIRP (see rules)
- Ignore multi-path.

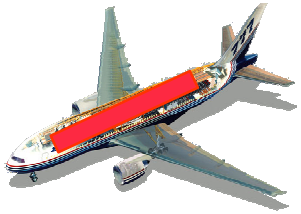
Market Definition

- All scheduled flights between North American city pairs
  - Reference OAG
  - Aircraft having greater than or equal to 100 seats
- Flights longer than 1 hour
- 23,333 Such Flights Flown on Friday

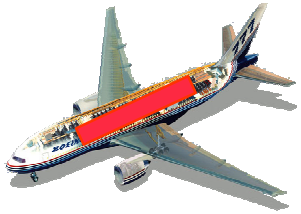


Estimating Average Aircraft Data Rates

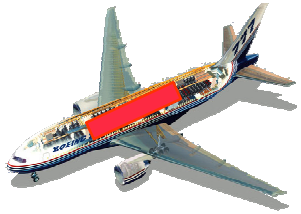
Number of Concurrent Broadband Users



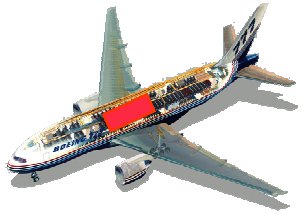
737
~200 Seats



Seat Load Factor 75%
150 Passengers

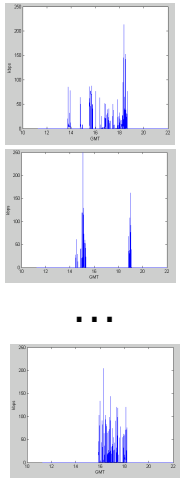


Penetration Rate 20%
30 Customers



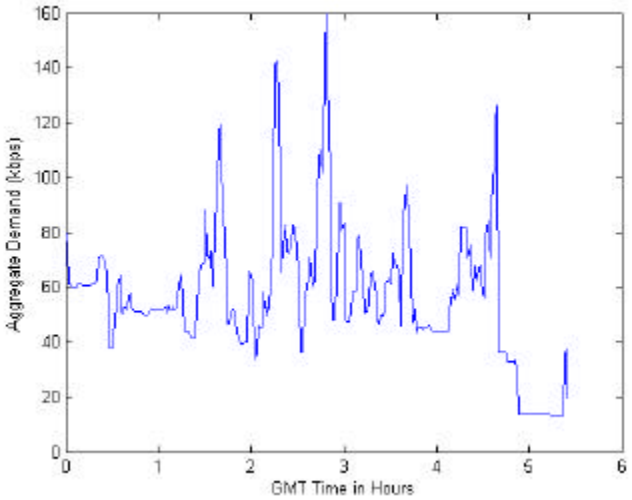
Activity Factor 50%
15 Concurrent Users

Broadband User Demand Aggregation



On-board Avg Single User Data Rate = 12 kbps

Off-board Avg Single User Data Rate = 3 kbps

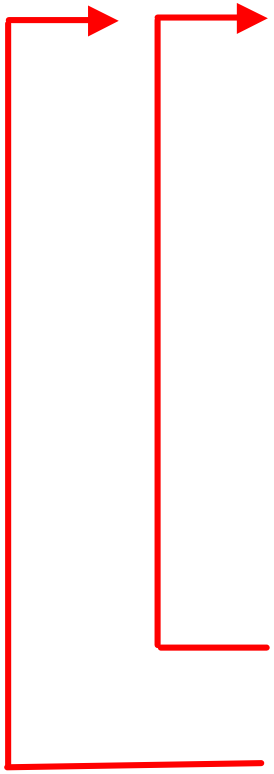


Average Aggregate On-board Aircraft Data Rate = 180 kbps

Average Aggregate Off-board Aircraft Data Rate = 45 kbps

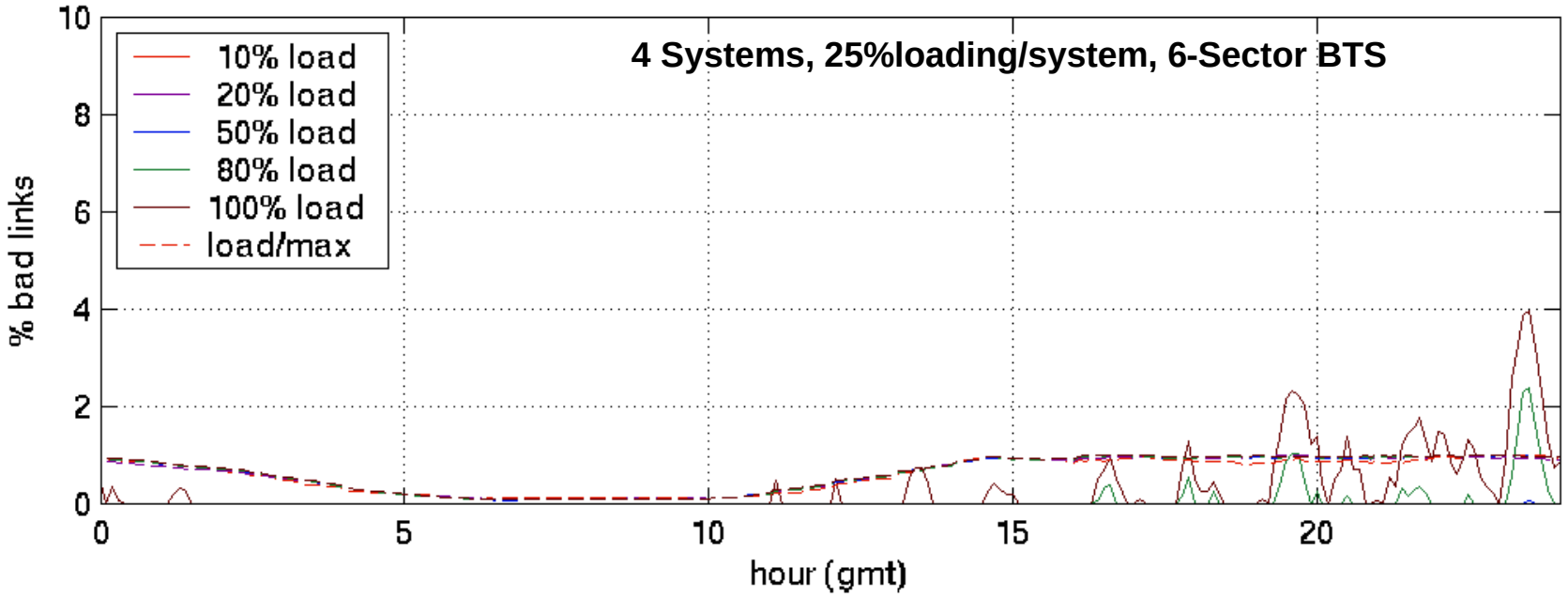
Simulation Algorithm

- **Fly aircraft on OAG schedule**
- **Simulate 24 hours on a Friday (heaviest traffic)**



- Calculate aggregate interference into each aircraft from all BTS within RH
- Calculate aggregate interference into each BTS sector from all aircraft within RH
- Calculate EIRP for each aircraft to close link to BTS in presence of said interference
- Calculate EIRP for each BTS to close link to each aircraft in the presence of said interference
- Loop until solution converges
- Move all aircraft forward one time step

Simulation Results

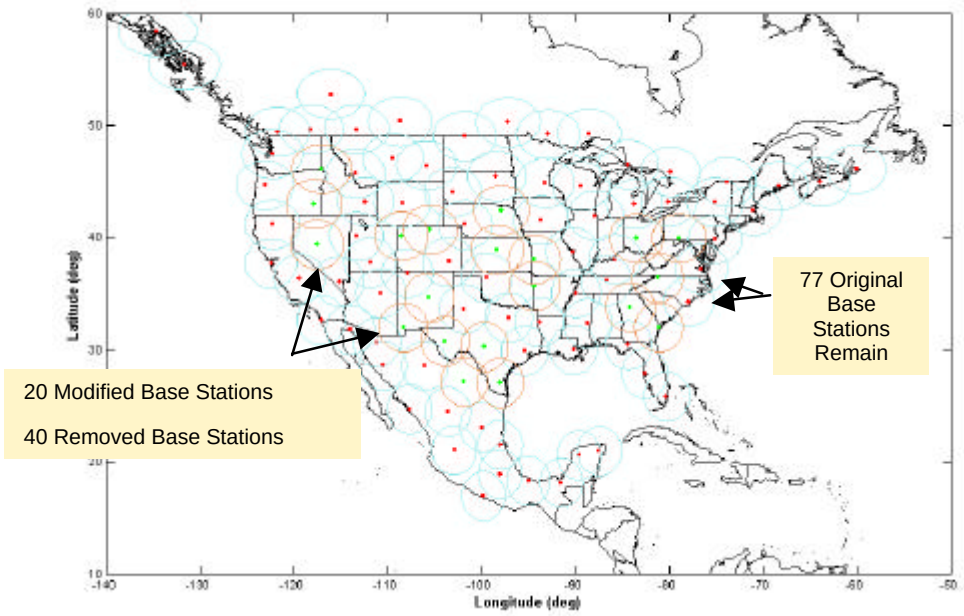


Conclusions:

- **Small percentage of links do not close at 100% market loading using 6-sector BTS.**
- **All links close with 10-sector BTS and 100% market loading.**
- **Results are even better with asymmetric loading between systems.**

Capacity Density and Verizon System Changes

- **It is more spectrally and economically efficient for service providers to increase local capacity by BTS sectorization rather than deployment of additional BTS.**
- **There is localized capacity saturation in the mid-west and northeast when only 6-sector antennas are used.**
- **Our simulation employs several 10-sector base stations in the densest traffic regions.**
- **Airfone's current network has excess base stations that are unnecessary for achieving capacity.**
- **Proposed separation rules require changes to Airfone's system:**
  - **40 stations unused**
  - **20 stations moved**
  - **77 of original base stations remain active in current locations**



- Even if Verizon Airfone were the sole ATG system, they would have to upgrade their system to use sectorized BTS and directional aero antennas to achieve sufficient capacity in the ATG.

- Coincidently, Verizon Airfone is already testing both directional aircraft antennas and 6-segment base station antennas using an FCC experimental license.

Operation Below 10,000’

- Boeing has assumed that continuous coverage below 10,000’ AGL is not a requirement for ATG systems
- We performed a technical analysis of commercial transport flights that shows 90% of flights spend less than 7 minutes below 10,000’ at takeoff and less than17 minutes on landing
- During the short time below 10,000’, FAA regulations require passengers to shut-off and stow electronic devices.
- The proposed rules do not provide continuous coverage below 10,000’.
  - Technical & business solutions are possible.
  - Solutions can be worked out in cooperation with FCC and other service providers.

Summary & Conclusions

- There are 2 approaches that allow multiple service providers to share the ATG band using 3G (CDMA) technology:
  - Shared & highly coordinated base stations
  - Dispersed and uncoordinated base stations
- Both approaches achieve the following goals:
  - Capacity to serve entire market
  - Simple and affordable technology
- Boeing favors the latter approach to avoid the drawbacks of current ATG rules.
- Boeing has proposed new rules for the latter approach that require BTS to be separated.
- Boeing has found through simulation that the latter approach supports up to 4 systems using “plain-old” base station technology if the BTS are located on a regular grid.
  - In practice, the margin provided by backing off to 3 systems accommodates some grid irregularity for real-world BTS siting requirements.